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TITLE: *UNIT CELL SIMULATION FOR CYLINDERS ON A TRIANGULAR PITCH*

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Unit Cell Simulation for Cylinders on a Triangular Pitch

by

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In criticality safety infinite arrays of identical units are frequently analyzed. For such analyses a unit cell is defined and, with appropriate boundary conditions invoked on the bounding surface(s) of the unit cell, a criticality calculation is performed. When properly done, this calculation is equivalent to calculating an infinite array of units. Sometimes the unit cell model exactly duplicates the actual unit cell in the array. In other cases, however, the calculational model can only be an "equivalent" simulation of the actual cell. One case involving the use of such equivalent cell models arises in an infinite array of cylindrical units on a triangular pitch. For such an array , each cylinder is in contact with six neighbors. The actual unit cell, therefore, consists of a cylinder enclosed in a hexagon with a flat-to-flat distance equal to the diameter of the cylinder. There are three commonly used ways to model the unit cell in such an array. The first is to model the close-packed cylinders exactly using four *hemicylinders* in a rectangular cuboid with reflective boundary conditions as available in KENO V.a[1] (Exact Model). The second way is to simulate the actual unit cell with a cylinder enclosed in a square (cuboid) bounding surface that has the same cross sectional area as that of the actual hexagon. Reflective boundary conditions are applied. This model results in a cylinder whose diameter is 93% of that of the actual cylinder. Atom density adjustments of both the cylinder material and the interstitial material are necessary to preserve masses. This is the model frequently employed by KENO IV[2] users (7% Reduced, Cuboid Model). The third model replaces the hexagon bounding surface of the actual cell with a cylindrical surface enclosing the same cross sectional area as the hexagon. A white boundary condition is used. This unit cell model is used in discrete ordinates (S_N) codes (Cylindrical Model).

In this paper we analyze the use of these equivalent unit cells for two problem-types of interest: a infinite lattice of small-diameter fuel pins and an infinite array of large shipping containers. Both void and water are considered as interstitial materials between the cylindrical units.

The fuel pins modeled are uranium nitride pins clad with tantalum and niobium with a diameter of 1.1 cm. The pins are infinitely long. The shipping container model is a 55 gallon drum with 13 cm thick insulation between the drum and the inner steel container. The fissile loading is a 6.5 kg sphere of plutonium inside the dry inner container.

Results of k_{eff} are shown in Table I. As can be seen, there is "exact" agreement (within statistics) among the models, thus confirming the neutronic equivalency of the three unit cell models *when properly used.*

As noted above, with the 7% Reduced Cuboid Model the atom densities of both the cylindrical unit and the interstitial material must be altered to preserve the total mass of materials present in the actual unit cell. Table II shows the effect of <u>not</u> altering the appropriate atom densities but, instead, simply using the atom densities for the exact model. For both the small diameter pins and the large shipping containers failure to properly alter the atom densities results in k_{eff}'s with nonnegligible errors. In three of the four cases the error is nonconservative, that is, it underpredicts k_{eff}. Thus, the correct modeling of an infinite array of cylindrical units on a triangular pitch with the 7% Reduced, Cuboid Model *requires adjustment of the appropriate atom densities* to ensure neutronic equivalency with the actual array.

References

1. L. M. Petrie and N. F. Landers, "KENO V.a: An Improved Monte Carlo Criticality Program with Supergrouping," NUREG/CR-200, Vol. 2, Section F11, ORNL/NUREG/CSD-2/V1/R2, December 1984.

2. L. M. Petrie and N. F. Cross, "KENO IV: An Improved Monte Carlo Criticality Program," Oak Ridge National Laboratory report ORNL-4938, November 1975.

Table 1. k_{eff} Comparisons for Unit Cell Models

Unit Cell Model	Fuel Pins		Shipping Containers	
	Void*	Water*	Void*	Water*
Exact	1.721±0.003	1.440±0.003	0.949±0.003	0.912±0.003
Cuboid with 7% Reduction	1.718±0.003	1.437±0.003	0.943±0.003	0.914±0.003
Cylindrical	1.718	1.440	-	-

* Interstitial Material

Table 2. Effect on k_{eff} of Not Altering the Atom Densities in the 7% Reduced Cuboid Model

Atom Density Treatment	Fuel Pins		Shipping Containers	
	Void**	Water**	Void**	Water**
Correctly Altered	1.718±0.003	1.437±0.003	0.943±0.003	0.914±0.003
Unaltered	1.790±0.003	1.303±0.003	0.876±0.003	0.882±0.003

** Interstitial Material